PCI Windows Driver Software
User's Manual

ACROMAG INCORPORATED
30765 South Wixom Road
Wixom, MI 48393-7037 U.S.A.

Tel: (248) 295-0310
Fax: (248) 624-9234

9500-280N

Contents

Introduction

PCI Windows Driver Software consists of low-level drivers and Windows Dynamic Link Libraries (DLLs) that facilitate the development of Windows applications accessing Acromag PMC I/O module products (e.g. PMC730), PCI I/O Cards (e.g. APC730), CompactPCI I/O Cards (e.g. AcPC730) and PCI Express XMC I/O modules (e.g. XMC-VLX85).

Notes:

- **The convention of this document is to refer to the above hardware devices using the generic name "PCI module."**
- **"PCIe" is used when it's necessary to distinguish PCI Express modules from their PCI counterparts.**

The software includes kernel drivers and DLLs for both 32 and 64-bit versions of Windows. Applications developed to run on 32-bit versions of Windows use the 32-bit kernel drivers and 32-bit DLLs. Applications developed to run on 64-bit versions of Windows use the 64-bit kernel drivers and either the 32-bit or 64-bit DLLs. Except where noted otherwise, the usage of the 32-bit and 64-bit DLLs is identical.

Notes:

- **64-bit versions of Windows support running both 32-bit and 64-bit applications. 32-bit applications run within the WoW64 subsystem. A 32-bit application must use the 32-bit DLLs and a 64-bit application must use the 64-bit DLLs. The 64-bit kernel driver is always used on 64-bit versions of Windows.**

- **The "bitness" of the Target system is important. The bitness of the Development system is not. For example, you can install PCISW-API-WIN on a 32-bit Windows system and use it to develop an application that will run on a 64-bit Windows target.**

DLL functions use the Windows _stdcall calling convention and can be accessed from a number of programming languages.

This document covers general information on hardware and software installation, programming concepts, application development and deployment issues. Also included in the PCI Window Driver documentation is a set of Function Reference documents for each Acromag PCI module DLL. After reviewing this user's manual, readers will next want to consult the Function Reference document specific to their hardware.

The older, 32-bit only versions of **PCISW-API-WIN** were based on a third party, 32-bit only kernel driver. To support 64-bit versions of Windows, new kernel drivers were developed and all the DLLs were updated. For a time **PCISW-API-WIN** was split into separate 32-bit and 64-bit products (**PCISW-API-WIN32** and **PCISW-API-WIN64**). If you are updating from -**WIN32**, **-WIN64**, or an earlier version of **PCISW-API-WIN**, please review the **Migrating from previous software versions** document. This document describes the differences between the various versions of the software, and outlines how to upgrade applications written against the old libraries.

Supported Hardware

The list of supported PCI and PCIe devices is shown in Table1.

Table 1: Acromag PCI and PCIe Modules

Model	Description
PCI230	8 Ch., 16-Bit DAC Outputs
PCI330	16 Bit (16DE/32SE) Analog Input Module
PCI341	12/14 Bit (16DE) Simultaneous Analog Input Module
PCI408	32 Non-Iso. Digital Inputs/Outputs (Low Side Sw.)
PCI424	Differential I/O Counter Timer Module
PCI464	Digital I/O Counter Timer Module
PCI482	10 16-bit counters – TTL
PCI483	4 16-bit counters – TTL and 4 32-bit counters – RS422
PCI484	6 32-bit counters – RS422
PCI520	8 Channel, Serial 232 Communication
PCI521	8 Channel, Serial 422/485 Communication
PCI730	Multi-Function Input/Output Board
PCIDX501	Reconfigurable, 500K gates, 64 TTL I/O
PCIDX502	Reconfigurable, 500K gates, 32 Differential I/O
PCIDX503	Reconfigurable, 500K gates, 24 Differential, 16 TTL I/O
PCIDX2001	Reconfigurable, 2M gates, 64 TTL I/O
PCIDX2002	Reconfigurable, 2M gates, 32 Differential I/O
PCIDX2003	Reconfigurable, 2M gates, 24 Differential, 16 TTL I/O
PCILX40	User-configurable Virtex-4 FPGA with 41,472 logic cells
PCILX60	User-configurable Virtex-4 FPGA with 59,904 logic cells
PCISLX150	User-configurable Spartan-6 FPGA with 147,433 logic cells
PCISX35	User-configurable Virtex-4 FPGA with 34,560 logic cells
PCIVFX70	User-configurable Virtex-5 FPGA with 71,680 logic cells and PowerPC Core
PCIVLX85	User-configurable Virtex-5 FPGA with 82,944 logic cells
PCIVLX110	User-configurable Virtex-5 FPGA with 110,592 logic cells
PCIVLX155	User-configurable Virtex-5 FPGA with 155,648 logic cells
PCIVSX95	User-configurable Virtex-5 FPGA with 94,208 logic cells
PCIe6VLX240	User-configurable Virtex-6 FPGA with 240k logic cells, no front I/O
PCIe6VLX240F	User-configurable Virtex-6 FPGA with 240k logic cells, SFP front I/O
PCIe6VLX365	User-configurable Virtex-6 FPGA with 365k logic cells, no front I/O
PCIe6VLX365F	User-configurable Virtex-6 FPGA with 365k logic cells, SFP front I/O
PCIe7A200AX	User-configurable Artix-7 FPGA with 200k logic cells, AXM I/O
PCIe7A200CC	User-configurable Artix -7 FPGA with 200k logic cells, conduction cooled
PCIe7K325AX	User-configurable Kintex-7 FPGA with 325k logic cells, AXM I/O
PCIe7K325CC	User-configurable Kintex-7 FPGA with 325k logic cells, conduction cooled
PCIe7K325F	User-configurable Kintex-7 FPGA with 325k logic cells, SFP front I/O
PCIe7K410AX	User-configurable Kintex-7 FPGA with 410k logic cells, AXM I/O
PCIe7K410CC	User-configurable Kintex-7 FPGA with 410k logic cells, conduction cooled
PCIe7K410F	User-configurable Kintex-7 FPGA with 410k logic cells, SFP front I/O
PCIeSLX150	User-configurable Spartan-6 FPGA with 150k logic cells
PCIeVLX85	User-configurable Virtex-5 FPGA with 85k logic cells
PCIeVLX110	User-configurable Virtex-5 FPGA with 100k logic cells
PCIeVLX155	User-configurable Virtex-5 FPGA with 155k logic cells

Supported Programming Languages

The demonstration program source code as well as the function descriptions and example code provided in the documentation, are all written in the C programming language. However, the library functions are also callable from numerous other languages. The DLL functions use the Windows _stdcall calling convention. Any programming language capable of calling the Windows API DLL functions should be able to call the PCISW-API DLL functions in a similar manner.

Getting Started

Software Installation

To install the PCI Windows Driver software on the development system, insert the software disk into the CD drive and run **Setup.exe**. Note that administrative rights are required to perform the installation.

Note:
The installation CD is used to install the complete driver software package on the development system (the system where your application will be written and built). Often, the target system (the system where your application will run) will be different than the development system. If your development and target systems are different, you will also want to read the **Deploying Applications to Target Systems** section of this document.

INSTALLED SOFTWARE

Program Menu Shortcuts

- Shortcut to installation directory (see below)
- Shortcut to this manual
- Shortcut to Enumeration utility (optional)
- Shortcut to executable demonstration programs (optional)

Installed Files

The default installation directory is `C:\Acromag\PCISW_API_WIN`.

Subdirectory	
c_examples	Microsoft Visual C++ example projects with source code. **Prebuilt 32-bit and 64-bit executables are in each project's Release directories**
c_include	Header files
c_lib	32-bit and 64-bit COFF format import libraries (segregated into Win32 and Win64 subdirectories)
config_files	Example VHDL object code for reconfigurable FPGA I/O Modules
docs	User's manual, DLL references, revision history, application notes
redist\DLLs	32-bit and 64-bit DLLs (segregated into Win32 and Win64 subdirectories)
redist\Driver	INF and catalog files for each board
redist\Driver\i386	32-bit device driver and co-installer DLL
redist\Driver\amd64	64-bit device driver and co-installer DLL
utility	32-bit and 64-bit PCIEnum utilities (segregated into Win32 and Win64 subdirectories)

Hardware Installation

1. Configure any jumpers on the PCI/PCIe module as necessary.
2. With power off, install the module into an available slot on the target system. Connect any field wiring at this time.
3. Turn on the system.

   XP and Vista:
   You will receive a dialog box shortly after boot-up asking if you want to install a driver for the new device. Answer yes and direct the New Hardware Wizard to the "redist\Driver" subdirectory (see table above) or to the optical drive containing the PCI Windows Driver disk or to some other directory with the required files (see note below). The New Hardware Wizard will copy and install the kernel mode driver.

   Windows 7 and 8:
   a. Launch Device Manager from the Control Panel (or type devmgmt.msc in the Search Box)
   b. Locate and right-click the "PCI Data Acquisition and Signal Processing Controller," select Update Driver, and browse to the driver files as described for XP and Vista.

Note
If you want to install the driver from a custom location (e.g. a flash drive) the following files must be present.

- The INF file for the board (e.g. PciLX60.inf). The same INF file is used to install both the 32-bit and the 64-bit drivers.
- The platform specific catalog file for the board (e.g. PciLX60_x64.cat). The catalog file is digitally signed by Acromag. It should be placed in the same directory as the INF file.
- The platform specific kernel driver (acrmgpci.sys) and co-installer (acrmgcls.dll). The kernel driver and co-installer must be placed in a subdirectory relative to the INF and catalog files. The 32-bit files must be in a subdirectory named "i386" and the 64-bit files must be in subdirectory named "amd64."

PCI Enumeration Utility

PCI Windows Driver Software includes a command line utility, **PCIEnum.exe** which may be run to display basic information about all installed Acromag PCI modules. Running this utility is a quick way to verify that the device driver and boards are properly installed. The displayed information includes the board name, board number, and the address and length of each memory range present. The board number is the value passed to the `PCIXXX_Open` function to open a connection to the device. (See the **Sequence of Operations** section below.)

Demonstration Programs

Console demonstration programs (source code provided) are included for each Acromag board. Each demo project can be built as both a 32-bit and a 64-bit application. Use the demo program to test your board and to become familiar with how it operates.

Tip:
Some of the more complicated demos include instructions on the main menu to walk you through some basic operations. Rather than jump back and forth between the instructions and the other menus, open two instances of the program and use one to display the instructions and the other to communicate with the board.

In some cases the main demo source file (PCIxxxDemo.c) will include comments with additional information necessary for running the demo (e.g. how channels should be wired together).

Where to Go From Here

1. Read the remainder of this document. It covers general concepts for using the software.
2. Read the function reference document for the library you will be developing with.
3. Study the source code for the demonstration program corresponding to your board. You can use this code as a starting point for your custom application.

Software Overview

The software includes 32-bit and 64-bit DLLs for each Acromag PCI module. In most cases the name of the DLL matches the name of the PCI module. For example the PMC464 is used with PCI464.dll. There are a few exceptions, however, where groups of similar PCI modules are supported by a single DLL. These include:

PCI Modules	**Shared DLL**
DX Series	PCIDX.dll
LX and SX Series	PCILX.dll
PCI VLX and VSX Series	PCIVLX.dll
PCIe SLX Series	PCIeSLX.dll
PCIe VLX Series	PCIeVLX.dll
PCIe 6VLX Series	PCIe6VLX.dll
PCIe 7K and 7A Series	PCIe7KA.dll

The DLLs provide the Application Programming Interface (API) used to access the hardware. Each DLL is written in C and contains functions using the _stdcall calling convention. The DLL is loaded and linked at runtime when its functions are called by an executable application. Multiple applications can access the functions of a single copy of a DLL in memory.

Tip:
The 32-bit and 64-bit DLLs share the same names and are installed into separate Win32 and Win64 directories on the development system. If you ever have a "loose" DLL and need to determine its type, right-click the file and view its Properties. The Version Description indicates whether the DLL is 32 or 64 bit.

Function Format

All PCI DLL functions have the following form:

```
status = PCIXXX_FunctionName(arg1, arg2, ... argn)
```

The "PCIXXX" portion of the function name indicates the PCI module the function is used with (e.g. PMC464). **Note that functions for PCI Express modules have a "PCIeXXX" prefix.**

Every function returns a 32-bit status value. This value is set to 0 when a function completes successfully or to a negative error code if a problem occurred. The following **Status Codes** section describes the values that may be returned from the DLL functions.

For most functions, *arg1* is an integer "handle" used to reference a specific PCI module. (See the **Sequence of Operations** section below.)

STATUS CODES

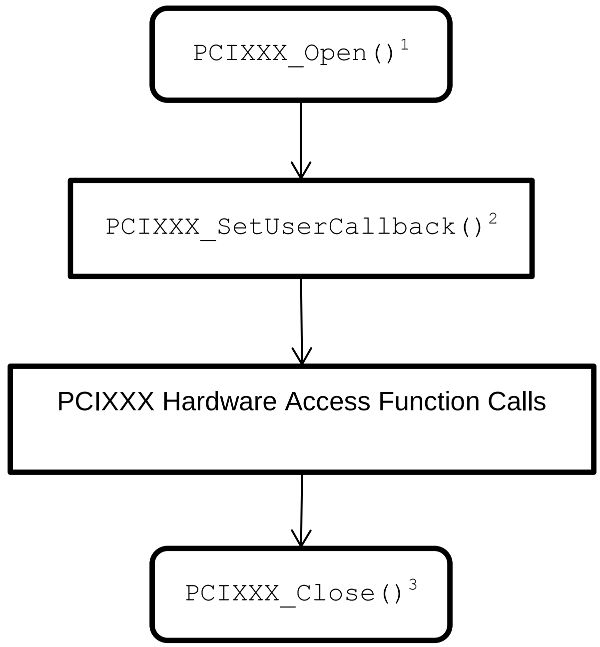
The table below summarizes the 32-bit status codes that may be returned from the DLL functions. Please note the return code of any failing functions if you should need to contact Acromag for technical support.

Value	Mnemonic	Description
0	ERR_OK	Operation Successful
-1	ERR_INVALID_HNDL	Returned if no board is associated with the specified handle. Applies to most functions.
-2	ERR_BOARD_IN_USE	Returned by *PCIXXX_Open()* if board is already open. This can occur if the board is in use by another application.
-4	ERR_CONNECT	Returned by *PCIXXX_Open()* if an error occurred connecting to the device. This will occur if the specified card number is invalid or if the kernel mode drivers are not properly installed or configured.
-5	ERR_MAPMEM	Returned by *PCIXXX_Open()* if an error occurred mapping the devices physical memory into the virtual address space.
-8	ERR_OUTOFHANDLES	Returned by *PCIXXX_Open()* if the maximum number of handles have already been allocated.
-9	ERR_BAD_PARAM	Returned by a function if it received an invalid parameter. This typically means the parameter was outside of the expected range or the function received a NULL pointer. Consult the individual function descriptions for other possible reasons for this error.
-10	ERR_INSUF_ RESOURCES	Returned by a function if there were insufficient resources to create a required data structure or carry out an operation.
-13	ERR_CONFIG_READ	Returned by PCIXXX_*ReadPCIReg* if an error occurred while reading data from the device's PCI configuration space.
-14	ERR_TIMEOUT	Returned by a function if it timed out before completing.
-15	ERR_CONFIG_SET	Returned by a Configuration function if the current settings used by this function do not represent a valid configuration
-16	ERR_CALIB	Indicates an error generating or using calibration data.
-17	ERR_BUFFER	Indicates an error occurred accessing a user defined data buffer
-18	ERR_CONFIG_WRITE	Returned by PCIXXX_*WritePCIReg* if an error occurred while writing data to the device's PCI configuration space.
-19	ERR_DMA_MAP	Returned by a DMA function if a DMA buffer is not mapped into the process
-20	ERR_EEPROM_ACK	Returned by EEPROM access functions if an Acknowledge is expected but not received
-21	ERR_EEPROM_ READBACK	Returned by EEPROM write if the value read from the EEPROM does not match value written
-22	ERR_FILE_OPEN	Returned if a file cannot be opened
-23	ERR_FILE_FORMAT	Returned if file contents are not in the expected format
-24	ERR_FILE_READ	Returned if a file cannot be read
-25	ERR_CONFIG_DONE	Returned by functions if the configuration of a re-configurable board is not complete
-26	ERR_EX_DESIGN	Returned by functions if a re-configurable board is not configured with the Acromag supplied example design

-27	ERR_HARDWARE	Returned if the hardware indicates an error or malfunction occurred
-28	ERR_FLASH_BUSY	Returned if a flash operation cannot be carried out because the flash chip is busy
-29	ERR_UNSUPPORTED	Returned if the device does not support the requested action
-30	ERR_CHECKSUM	Returned if a checksum mismatch is detected
-31	ERR_HANDLER	Returned if the function requires an interrupt handler and one has not yet been attached..
-35	ERR_INVALID_ CTRLHNDL	Returned if the kernel driver control handle is invalid

Sequence of Operations

Although each PCI module has its own DLL with unique functions, all PCI modules are accessed using the calling sequence shown below.



Notes:

1. PCIXXX_Open provides an integer "handle" used to access the specific PCIXXX module in all subsequent calls.
2. Not all Acromag PCI modules support interrupts. User callbacks are used to implement custom interrupt service routine logic for reconfigurable boards.
3. PCIXXX_Close should always be called for each "open" PCI module prior to terminating the application.

Interrupts

PCI Windows Driver Software supports callback functions for allowing your application to respond to interrupts generated in the hardware. Callback functions execute synchronously with the internal interrupt service routines (see below).

Each PCI DLL that supports interrupts has its own predefined internal interrupt service routine. (DLLs for reconfigurable boards are a special case. See note below.) The specifics of each routine are outlined in the PCI module's corresponding Function Reference document. If you choose to implement a callback function, you have the option of overriding this routine. This is done by setting a "*Replace*" parameter when designating the callback. (See **Callback Functions** below.)

When an interrupt occurs the following sequence of events takes place:

1. The kernel level driver disables the board's Interrupt Enable bit and signals the DLL's internal interrupt service routine (ISR).
2. At this point three things can happen
    a. If no callback was configured, the ISR simply processes the interrupt and then re-enables the board's Interrupt Enable bit.
    b. If a callback function was configured but should not override the internal ISR, the internal ISR processes the interrupt, re-enables the board's Interrupt Enable bit and then invokes the callback.
    c. If a callback function was configured to override the internal ISR, the ISR invokes the callback and then immediately returns without further processing. It is then the responsibility of the callback function to process the interrupt and re-enable the Interrupt Enable bit.

Note
The DLLs for user programmable FPGA boards include only a bare-bones ISR. When using interrupts, applications for these boards must include a callback function to implement the custom ISR logic. In other word, overriding the internal ISR is mandatory.

CALLBACK FUNCTIONS

When using the callback mechanism your application defines a function that the DLL will call from its internal interrupt service routine. The format of this function must exactly match that expected by the DLL. This format is hardware specific and is given in the **PCIXXX_SetUserCallback** topic in the PCI module's Function Reference document.

This format, however, will be some variation of the following:

C: `void _stdcall YourIsrName (int Handle, BYTE Status)`

The *Handle* argument identifies the board that caused the interrupt. If the function is not overriding the internal ISR, the Status variable(s) will contain data allowing you to determine the cause of the interrupt (e.g. the value read from a status register by the internal ISR). If the function is overriding the internal ISR, the Status variable(s) will be zero since the internal ISR did not read any registers prior to invoking the callback function.

SYNCHRONIZATION

The DLL's interrupt service routine (ISR) executes on a different thread than that of your application. Within the DLL the ISR (which includes the call to any callback function) is delimited as a device critical section. *PCIXXX_StartIsrSynch* and *PCIXXX_EndIsrSynch* can be used to synchronize other application threads with the ISR thread and to synchronize multiple threads within an application with each other.

Bracketing a section of code between calls of *PCIXXX_StartIsrSynch* and *PCIXXX_EndIsrSynch* defines that code as a device critical section. Two threads within a single process cannot execute critical section code simultaneously. *PCIXXX_StartIsrSynch* should be called by your application before it attempts to access data or device memory that can be accessed by another thread. Remember to call *PCIXXX_EndIsrSynch* when finished accessing these shared resources.

Base Address Pointers

Each DLL provides a function that returns the base address of the user mode mapping of the PCI module's memory space.

C and C++ programmers can cast the returned value to a pointer and access memory using normal pointer mechanisms. This method can be used to write additional functions that complement those provided through the DLL.

Example

```
/* Read PMC408 Digital Input Channel Register A */

UINT64 base_address;
volatile BYTE* pbase_addr;
WORD chan_val;

if (PCI408_GetBaseAddress(Handle, &base_address) == 0)
{
   pbase_addr = (BYTE*)base_address;
   chan_val = *(PWORD)(pbase_addr + 0x200);
}
```

Using the Library with Visual C++

This section describes the basic steps to add a PCI Windows Driver dynamic link library to a Visual C++ project. These instructions are based on the Microsoft Visual Studio 2010 development environment.

32-bit application

1. Open a new or existing Visual C++ project.
2. Open the project's property pages
3. Confirm the Platform drop-down is set to "Win32" and the Configuration drop-down is set to "All Configurations."
4. Add the path to the necessary header files (PCIXXX.h, PCIErrorCodes.h) to the project. To do this, open the **Configuration Properties | C/C++ | General** property page and modify the **Additional Include Directories** property. This can be a relative path.

   e.g. **..\..\..\c_include;**

   Add the path to the 32-bit import library (PCIXXX.lib) to the project.
   To do this, open the **Configuration Properties | Linker | General** property page and modify the **Additional Library Directories** property. This can be a relative path.

   e.g. **..\..\..\c_lib\Win32**

5. Select the **Configuration Properties | Linker | Input** property page and add the import library to the **Additional Dependencies** property

   e.g. **PCI408.lib**

6. Include the windows.h, PCIXXX.h and PCIErrorCodes.h header files at the beginning of your .c (C source code) or .cpp (C++ source code) files.

   e.g.
   ```
   #include <windows.h>
   #include "PCI408.h"
   #include "PCIErrorCodes.h"
   ```

64-bit application

1. Open a new or existing Visual C++ project.
2. Open the project's property pages
3. Confirm the Platform drop-down is set to "x64" and the Configuration drop-down is set to "All Configurations." (If x64 is not available, you will need to create the new platform in Configuration Manager.)
4. Add the path to the necessary header files (PCIXXX.h, PCIErrorCodes.h) to the project. To do this, open the **Configuration Properties | C/C++ | General** property page and modify the **Additional Include Directories** property. This can be a relative path.

   e.g. **..\..\..\c_include;**

   Add the path to the 64-bit import library (PCIXXX.lib) to the project.
   To do this, open the **Configuration Properties | Linker | General** property page and modify the **Additional Library Directories** property. This can be a relative path.

   e.g. **..\..\..\c_lib\Win64**

5. Select the **Configuration Properties | Linker | Input** property page and add the import library to the **Additional Dependencies** property

   e.g. **PCI408.lib**

6. Include the windows.h, PCIXXX.h and PCIErrorCodes.h header files at the beginning of your .c (C source code) or .cpp (C++ source code) files.

   e.g.
   ```
   #include <windows.h>
   #include "PCI408.h"
   #include "PCIErrorCodes.h"
   ```

Deploying Applications to Target Systems

This section outlines how to move your custom application from the development system to a target system where the driver software is not currently installed.

Kernel Driver Installation

The kernel driver for the Acromag board is installed on the target using the procedure outlined in the **Hardware Installation** section. The complete driver software package does not need to be installed on the system. Direct the New Hardware or Update Driver Software wizard to the PCI Windows Driver disk or to some other directory where the required files can be found.

The acrmgpci.sys driver will be installed to the \windows\system32\drivers directory.

Application and DLL Installation

The following files must be installed on the target machine.

- Your application program
- All DLL's corresponding to the PCI modules you are using. Copy these from the \redist\DLLs folder on the development system. These are typically installed in your application's directory.
- The PCI DLLs are dependent upon the Microsoft C Runtime Library (msvcr120.dll). If this file is not already present on the target, it can be copied from the \redist\DLLs folder on the development system Place the file in your application's directory.
- If your application program is dependent on additional components, those will need to be installed on the target system as well.

DLL Location Notes

To reduce the likelihood of "DLL Conflict" issues Microsoft recommends that DLLs be installed to the application directory with the program executable. This is the preferred location when running a single executable. However, if several applications will be simultaneously sharing a PCI DLL it is recommended that the DLL be placed in a common directory.

In order for the operating system to find a DLL, its location must be part of the Windows search order. The typical search order is as follows:

1. The directory from which the application is loaded
2. The current directory
3. The Windows system directory (e.g., C:\Windows\system32 or C:\Windows\SysWow64)
4. The Windows directory (e.g., C\Windows)
5. The directories listed in the PATH environment variable

The easiest solution to sharing a DLL is to place it in the Windows system directory. However, many applications store DLLs in these directories so using these locations creates the most risk for DLL conflict issues.

The technique used by the PCI Windows Driver Software installer is to append the common DLL directory (typically C:\Acromag\PCISW_API_WIN\redist\DLLs\Win32 or

C:\Acromag\PCISW_API_WIN\redist\DLLs\Win64) to the PATH environment variable. This allows the appropriate DLL to be located when running each example project.

MODIFYING THE PATH SETTING

Use the following steps if you wish to modify the PATH setting on a target machine.

Windows XP, Vista, 7 and 8

1. Launch the System applet from the Windows Control Panel.
2. Select the Advanced link (or tab) and then click the Environment Variables button.
3. Locate “Path” in the User Variables or System Variables. The PATH is a series of one or more directories separated by semicolons.
4. Edit the variable by appending the path to the common DLL directory to the right of the existing value.
5. Click OK